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MECHANICS

Experimental Determination of Damping of Plate Vibrations in a Viscous Fluid

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Abstract—A method of determining the aerodynamic-drag coefficient of flat vibrating plates from the vibrogram of free damping vibrations of cantilever-fixed duralumin samples has been developed. From the results of our experiments, simple approximating formulas determining the decrement of damping vibrations and the aerodynamic-drag coefficient through the dimensionless vibration amplitude and the Stokes parameter are proposed. The approach developed in this study for determining the aerodynamic-drag coefficient of a vibrating plate can be a useful alternative to purely hydrodynamic methods of finding the drag of vibrating solids.

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INTRODUCTION

Recently, interest in investigations of mechanical vibrations of plates in a motionless viscous liquid has increased. The motivation comes from multiple practical applications including atomic-force microscopy, sensors and drives of heads on micromechanical generators, cooling devices, and offshore engineering. Our attention to this problem is associated with the approach developed in [1, 2] for determining the damping properties of a material by investigation of damping flexural vibrations of cantilever-fixed flat test samples.

In the general case, the problem of taking into account the aerodynamic forces acting on a cantilever-fixed plate is extremely complex mainly because of the complexity of three-dimensional gas flows caused by the plate vibrations. The known approaches [3, 4] are based here on the assumption that the length of the plate considerably exceeds its width. In this case, the length of a vibration wave on low structural vibration modes greatly exceeds the plate deviations due to which the plate can be considered as locally flat. The detailed study on the three-dimensional modeling of flows near thin consoles carried out in [5] shows the acceptability of the two-dimensional approach in a wide range of ratios between the length and width of the plate. Thus, the problem of determination of the aerodynamic drag of a vibrating flat plate is directly related to the problem of extracting the aerodynamic component in the logarithmic decrement of free vibrations (LDV) of a console.

The difficulty in the direct determination of the aerodynamic component of damping from the experimental LDV consists in the presence of other contributions to the vibration decrement from the structural and internal damping. When using duralumin plates, however, neither one nor the other depend on the plate-vibration amplitude [6, 7], and the LDV dependence on the vibration amplitude is completely determined by the aerodynamic component. Precisely this fact makes it possible to extract the aerodynamic component of damping from the LDV measured in experiments and to restore the aerodynamic drag of the vibrating plate.

EXPERIMENTAL MEASUREMENTS

For measuring the LDV δ for the cantilever-fixed plate harmonically vibrating in air (Fig. 1a), we carried out a series of experiments on measuring the deviation of its free end from the equilibrium position. The amplitude was measured using a laser distance sensor which detects the deviation of the free end from its equilibrium position (the plate-vibration vibrogram). In the experimental installation, the triangulation laser sensor RF603-X/100 operating in the range of 100–150 mm with a sampling rate of 2 kHz providing an accuracy of 0.01 mm in measurement of the vibration amplitude was used.

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